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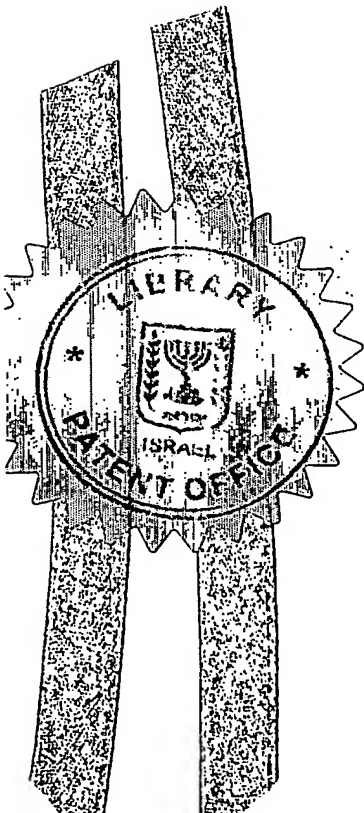
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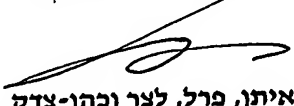
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(בעברית)
(Hebrew)

DIAGNOSTIC DEVICE USING DATA COMPRESSION

(באנגלית)
(English)

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DIAGNOSTIC DEVICE USING DATA COMPRESSION

מכשיר דיאגנוסטי המשתמש בדילול מידע

Eitan, Pearl, Latzer & Cohen-Zedek

P-4333-IL1

DIAGNOSTIC DEVICE USING DATA DILUTION

FIELD OF THE INVENTION

The present invention relates to an in vivo device, system and method such as for
5 imaging the digestive tract; more specifically, to an in vivo device, system and method where
information transmitted or sent, is compressed.

BACKGROUND OF THE INVENTION

10 Devices and methods for performing in-vivo imaging of passages or cavities within
a body, and for gathering information other than or in addition to image information (e.g.,
temperature information, pressure information), are known in the art. Such devices may
include, inter alia, various endoscopic imaging systems and devices for performing
imaging in various internal body cavities.

An in-vivo imaging device may include, for example, an imaging system for
15 obtaining images from inside a body cavity or lumen, such as the GI tract. The imaging
system may include, for example, an illumination unit, such as a set of light emitting
diodes (LEDs), or other suitable light sources. The device may include an imaging sensor
and an optical system, which focuses the images onto the imaging sensor. A transmitter
and antenna may be included for transmitting the images signals. A receiver/recorder, for
20 example worn by the patient, may record and store image and other data. The recorded
data may then be downloaded from the receiver/recorder to a computer or workstation for
display and analysis. Such imaging and other devices may transmit data such as image
data or other data during a certain period of time. It may be desirable to limit the amount
of time spent transmitting image data, and also the bandwidth required for such a
25 transmission. The time spent transmitting limits the amount of image or other data that
may be transmitted. Other in-vivo diagnostic units need not transmit by radio waves, for
example, image or other data collected may be sent via wire.

Therefore, there is a need for an in-vivo diagnostic device, such as an imaging
device, which more efficiently transmits data.

SUMMARY OF THE INVENTION

An embodiment of the device, system and method of the present invention enables the obtaining of in vivo images from within body lumens or cavities, such as images of the gastrointestinal (GI) tract, where the data such as image data is typically transmitted or otherwise sent to a receiving system. According to an embodiment of the invention, the data transmitted, including, for example, image information, is compressed.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a schematic diagram of an in vivo imaging system according to one embodiment of the present invention;

Fig. 2 depicts a series of steps of a method according to an embodiment of the present invention;

Fig. 3 depicts a schematic diagram of a first exemplary dilution pattern for selecting pixels according to an embodiment of the present invention;

Fig. 4 depicts a schematic diagram of a second exemplary dilution pattern for selecting pixels according to an embodiment of the present invention;

Fig. 5 depicts a schematic diagram of pixels of one color selected according to an exemplary dilution pattern in accordance with the present invention; and

Fig. 6 depicts a schematic diagram of partial reconstruction of an image based on pixels selected according to an exemplary dilution pattern in accordance with the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

In the following description, various aspects of the present invention will be described. For purposes of explanation, specific configurations and details are set forth in order to provide a thorough understanding of the present invention. However, it will also be apparent to one skilled in the art that the present invention may be practiced without the specific details presented herein. Furthermore, well-known features may be omitted or simplified in order not to obscure the present invention.

Embodiments of the system and method of the present invention are preferably used in conjunction with an imaging system or device such as described in U.S. patent 5,604,531 to Iddan et al. and/or in application number WO 01/65995 entitled "A Device

And System For In Vivo Imaging”, published on 13 September, 2001, both of which are hereby incorporated by reference. However, the device, system and method according to the present invention may be used with any device providing imaging or other data from a body lumen or cavity. In alternate embodiments, the system and method of the present invention may be used with devices capturing information other than image information within the human body; for example, temperature, pressure or pH information, information on the location of the transmitting device, or other information.

Reference is made to Fig. 1, which shows a schematic diagram of an in vivo imaging system according to one embodiment of the present invention. In an exemplary embodiment, a device 40 is an ingestible capsule capturing images, but may be another sort of device and may collect information other than image information. Typically, device 40 includes at least one sensor such as an imager 46, for capturing images, a processing chip or circuit 47 that processes the signals generated by the imager 46, and one or more illumination sources 42, for example one or more “white LEDs” or any other suitable light source, for illuminating the body lumen. An optical system 50, including, for example, one or more optical elements (not shown), such as one or more lenses or composite lens assemblies (not shown), one or more suitable optical filters (not shown), or any other suitable optical elements (not shown), may aid in focusing reflected light onto the imager 46 and performing other light processing. Processing chip 47 need not be a separate component; for example, processing or a processing chip may be integral to the imager 46. The sensor may be another type of sensor, such as a temperature sensor, a pH sensor, or a pressure sensor.

Device 40 typically includes a transmitter 41, for transmitting image and possibly other information (e.g., control information) to a receiving device, and a compression module 600, for compressing data. The transmitter 41 is typically an ultra low power radio frequency (RF) transmitter with high bandwidth input, possibly provided in chip scale packaging. The transmitter may transmit via an antenna 48. The transmitter 41 may also include circuitry and functionality for controlling the device 40. Typically, the device includes a power source 45, such as one or more batteries. For example, the power source 45 may include silver oxide batteries, lithium batteries, or other electrochemical cells having a high energy density, or the like. Other power sources may be used.

Other components and sets of components may be used. For example, the power source may be an external power source transmitting power to the capsule, for example as

described in a patent application with International Publication Number WO 02/080753 A2, and a controller separate from the transmitter 41 may be used.

In one embodiment, the imager 46 is a complementary metal oxide semiconductor (CMOS) imaging camera. The CMOS imager is typically an ultra low power imager and is provided in chip scale packaging (CSP). One suitable CMOS camera is, for example, a "camera on a chip" CMOS imager specified by Given Imaging Ltd. of Israel and designed by Photobit Corp. of California, USA, with integrated active pixel and post processing circuitry. Other types of CMOS imagers may be used. In another embodiment, another imager may be used, such as a CCD imager, or another imager.

Typically, the device 40 is swallowed by a patient and traverses a patient's GI tract, however, other body lumens or cavities, such as blood vessels, the female reproductive tract, etc., may be imaged or examined. The device 40 transmits image and possibly other data to components located outside the patient's body, which receive and process the data. Preferably, located outside the patient's body in one or more locations, are a receiver 12, preferably including an antenna or antenna array 15, for receiving image and possibly other data from device 40, a receiver storage unit 16, for storing image and other data, a data processor 14, a data processor storage unit 19, a data decompression module 610 for decompressing data, and an image monitor 18, for displaying, *inter alia*, the images transmitted by the device 40 and recorded by the receiver 12. Typically, the receiver 12 and receiver storage unit 16 are small and portable, and are worn on the patient's body during recording of the images. Preferably, data processor 14, data processor storage unit 19 and monitor 18 are part of a personal computer or workstation, which includes standard components such as a processor 13, a memory (e.g., storage 19, or other memory), a disk drive, and input-output devices, although alternate configurations are possible. In alternate embodiments, the data reception and storage components may be of another configuration. Further, image and other data may be received in other manners, by other sets of components. Typically, in operation, image data is transferred to the data processor 14, which, in conjunction with processor 13 and software, stores, possibly processes, and displays the image data on monitor 18. Other systems and methods of storing and/or displaying collected image data may be used.

Typically, the device 40 transmits image information in discrete portions. Each portion typically corresponds to an image or frame. Other transmission methods are possible.

For example, the device 40 may capture an image once every half second, and, after capturing such an image, transmit the image to the receiving antenna. Other capture rates are possible. Typically, the image data recorded and transmitted is digital color image data, although in alternate embodiments other image formats (e.g., black and white image data) may be used.

5 In one embodiment, each frame of image data includes 256 rows of 256 pixels each, each pixel including data for color and brightness, according to known methods. For example, in each pixel, color may be represented by a mosaic of four sub-pixels, each sub-pixel corresponding to primaries such as red, green, or blue (where one primary is represented twice). In other embodiments, each pixel may capture only one color. The brightness of the
10 overall pixel may be recorded by, for example, a one byte (*i.e.*, 0-255) brightness value. Other data formats may be used.

In some embodiments of the device, system and method of the present invention, diagnostic data need not be transmitted, but may be sent via another method, such as via wire. For example, in an endoscope device, an imaging device at one end may send the data via
15 wire to a receiving device.

It may be desirable to limit the amount of time spent transmitting image data, and/or the bandwidth required for such a transmission. Embodiments of the system and method of the present invention compress image and possibly other data before transmission. Since compressed data takes less time to transmit, more data may be transmitted, and more frames
20 of image data may be transmitted per time unit, without increasing the bandwidth of the transmitter. Alternatively, the same amount of data may be transmitted using less bandwidth. Another aspect of the data transmission relates to the transmission systems with limited energy source. In this case smaller amount of bits needed to be transmitted may enable more energy per bit in the transmission. Data other than or in addition to image data may be
25 transmitted and compressed. For example, control information may be compressed. Furthermore, in devices transmitting telemetric information other than image information, such as pressure or pH information, such information may be compressed. In further embodiments, image data need not be transmitted in discrete portions corresponding to images.

30 Thus, for example, if the bandwidth of a transmission mechanism permits an uncompressed frame relay rate of, for example, two frames per second at a specified bitrate, the same transmission mechanism can support the transmission of a greater number of frames

per second using the same bitrate if the transmitted data is compressed or diluted prior to compression, and then reconstructed after transmission. Thus, according to one embodiment, for areas of the gastro-intestinal tract where a greater number of frames per second is desired (for example, the esophagus, which may be traversed quickly by a capsule), the imaging
 5 device may operate in a "fast mode" which transmits compressed or diluted data and is therefore capable of transmitting a greater number of frames per second than uncompressed data.

In an exemplary embodiment of the present invention, device 40 includes a data compression module 600 for compressing data transmitted from the device 40 and for
 10 providing the data to the transmitter 41, possibly via intermediate circuitry. Data compression module 600 may be implemented as part of a microprocessor or ASIC or other micro-computing device, or as part of the imager 46 or processing chip 47. In alternate embodiments the functions of the data compression module 600 may be taken up by other structures and may be disposed in different parts of the device 40. For example, the
 15 transmitter 41 may include data compression capability, or data compression module 600 may be a stand-alone unit, or may be implemented in software.

In one embodiment, transmitter 41 includes at least a modulator 70 for receiving the video signal from the imager 46, a radio frequency (RF) amplifier 72, and an impedance
 20 matcher 74. The modulator converts the input image signal having a cutoff frequency f_c of less than 5 MHz to an RF signal having a carrier frequency f_r , typically in the range of 1 GHz. While in one embodiment the signal is an analog video signal, the modulating signal may be digital rather than analog. The carrier frequency may be in other bands, *e.g.* a 400MHz band. The modulated RF signal has a bandwidth of f_t . The impedance matcher matches the
 25 impedance of the circuit to that of the antenna. Other transmitters or arrangements of transmitter components may be used, utilizing different signal formats and frequency ranges. For example, alternate embodiments may not include a matched antenna or may include a transmitter without a matching circuit. In one embodiment of such an imaging device 40, transmission occurs at a frequency of 434MHz, using Phase Shift Keying (PSK). In alternate
 30 embodiments, other transmission frequencies and methods (such as AM or FM) may be used.

The receiver 12 preferably detects a signal having the carrier frequency f_r and the bandwidth f_c described hereinabove. The receiver 12 may be similar to those found in televisions or it may be one similar to those described on pages 244-245 of the book

Biomedical Telemetry by R. Stewart McKay and published by John Wiley and Sons, 1970. The receiver may be digital or analog. In alternate embodiments, other receivers, responding to other types of signals, may be used.

5 The receiver 12 preferably includes a data decompression module 610 for decompressing data received from the device 40. In exemplary embodiment data decompression module 610 is a microprocessor or other micro-computing device and is part of the receiver 12. In alternate embodiments the functions of the data decompression (decoding) module 610 may be taken up by other structures and may be disposed in different parts of the system; for example, data decompression module 610 may be implemented in
10 software and/or be part of data processor 14. The receiver 12 may receive compressed data without decompressing the data and store the compressed data in the receiver storage unit 16. The data may be later decompressed by, for example data processor 14.

Preferably, the transmitter 41 provides overall control of the device 40; in alternate embodiments control may be provided by other modules. Preferably, the data
15 compression module 600 interfaces with the transmitter 41 to receive and compress image data; other units may provide other data to data compression module 600. In addition, the data compression module 600 may provide the transmitter 41 with information such as, for example, start or stop time for the transfer of image data from the data compression module 600 to the transmitter 41, the length or size of each block of such image data, and
20 the rate of frame data transfer. The interface between the data compression module 600 and the transmitter 41 may be handled, for example, by the data compression module 600. Typically, the data compression module 600 compresses image information in discrete portions. Each portion typically corresponds to an image or frame. Other compression methods or sequences are possible, and other units of compression and transmission are
25 possible. One of the other possibilities to compress the image data is to compare the subsequent images, and to transmit only differences between these images rather than each image. Assuming that in most cases the subsequent images are similar, the difference between the images will contain much less information than the image itself.

In alternate embodiments, the data exchanged between the data compression
30 module 600 and the transmitter 41 may be different, and in different forms. For example, size information need not be transferred. Furthermore, in embodiments having alternate arrangements of components, the interface and protocol between the various components

may also differ. For example, in an embodiment where a data compression capability is included in the transmitter 41 and the imager 46 transfers un-compressed data to the transmitter 41, no start/stop or size information may be transferred.

The data compression module 600 and data decompression module 610 may use various data compression formats and systems. Compression formats used may include compression formats where some data is lost during compression and compression formats where data is not lost during compression. Typically, the data compression module 600 and decompression module 610 include circuitry and/or software to perform such data compression. For example, if the data compression module 600 or decompression module 610 are implemented as a computer on a chip or ASIC, data compression module 600 or decompression module 610 may include a processor operating on firmware which includes instructions for a data compression algorithm. If data decompression module 610 is implemented as part of data processor 14 and/or processor 13, the decompression may be implemented as part of a software program. It will be evident to those of skill in the art that compression module need not be a physically separate component, but rather, that its functionality may be performed by another component, such as imager 46.

The amount of imager data to be sent may be, for example, over 1.35 Megabits per second. Compression may significantly reduce this amount. After compression, and before transmission, randomization may occur (performed, for example, by the transmitter 41). Namely, the occurrence of the digital signals ("0" and "1") may be randomized so that transmission is not impeded by a recurring signal of one type.

Fig. 2 depicts a series of steps of a method according to an embodiment of the present invention. Referring to Fig. 2, in block 200, an in-vivo device, such as a swallowable capsule, captures image data. Typically, an imager within the device captures image data of a gastrointestinal tract, but other image data may be captured, for example, image data from other body lumens or cavities. Data other than or in addition to image data may be captured.

In block 210, the image data is compressed. Such compression is typically in response to a process receiving input data corresponding to an image. In the embodiment shown in Fig. 2, compression may be accomplished by diluting the captured data, or by selecting only a pattern of pixels for transmission. Such creation of a selection of data may be, for example, performed according to a dilution pattern. The image data may be first

loaded or transferred from the imager to a compression module, or, alternately or additionally, compressed at the imager. Data other than or in addition to image data may be compressed. For example, data may be selected for transmission by the imager and then further compressed, for example, by JPEG or another algorithm before transmission.

5 In block 220, the data is transmitted to a receiver. Typically, the data, such as image data, is transmitted using radio waves (RF channel) to a receiver external to the body, but other methods may be used. In alternate embodiments, the image or other data may be sent by other methods, such as by wire.

10 In block 230, the data is decompressed, enabling reconstruction of the image. Reconstructed image data may be, for example, displayed or stored for later use. Alternately, the compressed image data may be stored for later image reconstruction.

Other steps or series of steps may be used than those described in the above blocks.

The data compression methods described herein may be lossless or lossy. Lossless data compression enables precise (with no distortion) decoding of the compressed data. The compression ratio of lossless methods is however limited. Lossy compression methods do not enable precise decoding of the compressed information. However the compression ratio of lossy methods may be much higher than of the lossless method. In many cases the data distortion of the lossy methods is non-significant, and the compression ratio is high. Without limitation of generality, the description of data compression schemes herein may be applicable both to lossless and to lossy methods.

20 In an embodiment of the present invention, compression may be accomplished by transmitting only portions of the captured image selected according to a dilation pattern. While this may result in some loss of quality in the resulting image, proper selection of pixels according to a suitable dilation pattern, together with proper reconstruction of the diluted image, may preserve the quality of the transmitted image and rehabilitate the image to lossless or near-lossless condition. The dilation pattern may be predetermined or may be selected or created by a component of the device based on operating conditions related, for example, to its position in the gastro-intestinal tract or other surrounding conditions such as pH, temperature, ambient lighting or color conditions. Data may be selected for transmission by means other than a dilation pattern.

30 Two embodiments of the invention are presented herein as two dilation patterns, although those of skill in the art will recognize that other dilation patterns may be used for

compressed transmission in accordance with the present invention. In the below exemplary dilution patterns presented, there is assumed an imager with 256 rows and 256 columns of pixels, each pixel representing one of the colors red, blue or green. The embodiments also show an imager having twice as many green pixels as red or blue pixels. It will be recognized by those of skill in the art that the invention may be practiced with imagers of different configurations, sizes, and color patterns. For example, a black and white imager may be used.

Fig. 3 depicts one exemplary dilution pattern in accordance with embodiments of the invention that may be used in an imager having, for example, pixels representing red (R) 302, green (G) 304, and blue (B) 306 in the arrangement shown. In this first exemplary dilution pattern shown, the imaging device may transmit every, for example, fourth pixel in each row, where, typically, all pixels chosen in any row represent the same color. In the case of three colors, e.g., red, blue and green, one color selected for transmission may repeat every second row, while the selection of the other two colors alternates every fourth row. Thus, for example, in the example shown, in two of each four consecutive rows, the color red 308 is selected, while in the remaining two rows, blue 310 and green 312 alternate every fourth row. Thus, if the array of pixels in the imager includes 256 rows and 256 columns, the device may transmit only 64 pixels, or every fourth pixel, for each row.

Fig. 4 depicts a second exemplary dilution pattern that may be used in accordance with embodiments of the invention. In this second exemplary dilution pattern, a pattern is repeated every four rows, in which no pixels are transmitted from a first row, every fourth pixel is transmitted from each of the next two rows, and every second pixel is transmitted from the fourth row. In this embodiment, it will be recognized that twice as many green pixels 402 are transmitted than red pixels 404 or blue pixels 406.

According to some embodiments of the present invention, the device may transmit for some or all pixels the difference between the actual value and a predicted value based on the already determined values of other pixels, for example, neighboring pixels. By this method, the receiver may determine the predicted value based on the values of the other pixels, and modify the predicted value by the difference transmitted, thereby reconstructing the original actual value for the pixel. It will be recognized that this embodiment of the invention may be implemented as lossless or lossy. For example, in one embodiment, for each pixel there may be transmitted either a value or an exact difference based on a predicted value for the pixel. In such an embodiment, no image quality in the reconstructed image will

be lost. In another example, there may be set a threshold, wherein a difference between the predicted value and the actual value that is less than the threshold is not transmitted. In this latter example, some image quality in the reconstructed image may be compromised.

5 It will be recognized by those of skill in the art that while only several dilution patterns have been discussed at length, any suitable dilution pattern that selects some pixels for transmission while omitting others may be used in accordance with embodiments of this invention.

10 Optionally, devices in accordance with embodiments of the invention may operate in either of the above "simple" fast modes or in an "averaging" fast mode corresponding to any dilution pattern, including, for example, either of the two exemplary modes discussed above. In "averaging" mode, the value transmitted for a selected pixel of a certain color may be summed or averaged or otherwise affected by the value of a nearby pixel, typically a pixel of the same color. For example, in Fig. 3, a pixel 308 selected by the particular dilution pattern for transmission may be averaged by the imager with a neighboring pixel of the same color
15 302 prior to transmission. Averaging may be performed by the compression module, for example, the imager, or by another component. This "averaging mode" may be activated or deactivated, for example, by a control bit intrinsic or extrinsic to the compression module, for example, the imager. It will be appreciated by those of skill in the art that any modification of an input pixel by reference to one or more neighboring pixels, for example a weighted
20 average, may be used in accordance with the present invention.

Also optionally, in an embodiment of the present invention, there may be provided an error correction mechanism for detecting and correcting errors. In some embodiments, control or "overhead" information is transmitted in addition to the pixels of each image, for example, information contained in a prefix header and/or suffix word.
25 This control information may or may not be compressed. Various techniques of error correction are known, any of which may be used in connection with any embodiment of the present invention. In some embodiments of the invention, the imager may perform error correction encoding.

At the receiver end, various methods may be used in accordance with
30 embodiments of the present invention to reconstruct an image from the diluted data transmitted. The method of reconstruction may vary depending on the dilution pattern chosen.

In an embodiment of the invention employing the first exemplary dilution pattern, a full matrix of color values for each pixel may be reconstructed from the selected pixels using various methods. For example, as shown in Fig. 5, the sampled red pixels 502 in the first dilution pattern are in a rhomboid pattern. In one embodiment of the present invention, some or all of the values of four pixels 602 forming a rhomboid may be used to calculate a value for the pixel at the center of the rhomboid, as depicted by the pixels 604 in Fig. 6. While in one embodiment of the present invention, the four values surrounding a rhomboid center may be averaged, other embodiments are of course possible. For example, for some pixels located on the edge of an object, the center value may be determined by a weighted average of the four surrounding pixels. Whether the pixel is on an edge may, for example, be determined based on the gradient at that pixel. Alternately or additionally, the center value may be determined by a weighted average of a subset of the surrounding pixels. In one embodiment, the center value may be determined based on the median of some or all of the surrounding pixels. In one embodiment, the interpolation may be on a grid not necessarily in the shape of a square. Next, for example, the orthogonal values between the pixels may be obtained by interpolation of the four surrounding pixels. Any known method may be used for this interpolation, for example, linear, quadratic, bicubic, polynomial or other interpolation. Finally, the remaining pixels, which may be located on diagonals between originally selected pixels, may be interpolated using known methods.

With respect to the remaining two colors in the first dilution pattern, the missing pixels may be interpolated from the square pattern shown in Fig. 6 by any known method of interpolation, for example, linear, quadratic, bicubic, polynomial or other interpolation. The remaining pixels, which may be located on diagonals between originally selected pixels, may be interpolated using known methods. While only some methods of interpolation of missing pixels have been enumerated, it will be understood by those of skill in the art that any suitable method of interpolation may be used consistent with any embodiment of the present invention.

With respect to reconstructing image data in accordance with the second exemplary dilution pattern, a similar reconstruction process may be used as the one described above. Thus, for example, the rhomboid pattern created by the sampled green pixels is similar to the rhomboid pattern of the red pixels in the first exemplary dilution

pattern, and the pixels of the remaining two colors are in a square pattern. It will be understood by those of skill in the art that the present invention is not limited in the respect of the exemplary dilution patterns (and reconstruction schemes) described above, and that many others may be used in accordance with the present invention.

5 In some embodiments of the present invention, there may be further enhancement or refinement of the reconstructed image. In some embodiments of the present invention, the resulting image may be smoothed by modifying the color values of the originally selected pixels, for example, by replacing the original value by a weighted average of the original value taken together with some or all values of the surrounding selected pixels, for
10 example, a median value of the surrounding pixels.

The various compression and/or dilution methods discussed herein need not be used with a device having more than one mode, or a "fast mode", but may be utilized for various other purposes. Further, compression and dilution of pixels need not be used together.

15 Typically, a compression and/or dilution process is carried out by control circuitry in the device 40, such as transmitter 41. Similarly, reconstruction and/or decompression may be carried out by data processor 14, decompression module 610, processor 13, etc., or by structures in the receiver 12. Of course, in other embodiments, such processes may be carried out by other components, and of course the methods discussed herein may be
20 carried out in devices having structures other than that of device 40, receiver 12, and data processor 14. For example, control processes such as producing the selection of input data may be carried out by an imaging component, or another component. For example, a portion of a controller may be considered to be within the imaging unit.

Furthermore, in some embodiments of the present invention, enhancement may be
25 made by modifying the intensity values of the image to restore them to near the original values. For example, the intensity of a reconstructed pixel may be calculated using only or predominantly the values of nearby originally selected pixels. In another embodiment, intensity for each pixel may be obtained by using the values of pixels of only one color, for example, green. It will be recognized that other methods of obtaining intensity values for
30 reconstructed pixels may be used consistent with embodiments of this invention.

In some embodiments of the present invention, there may be lessening of color artifacts due to the process of dilution and reconstruction of the image, for example, by

suppressing colors of pixels located on edges found in the image. In some embodiments of the invention, color suppression may also be used to correct color-saturated pixels.

In some embodiments of the present invention, a pre-processing block may be added for the original samples. For example, in one embodiment, a gradient evaluation for enhancing edges may be added. Additionally, in one embodiment of the invention, a post-processing block may be added for correcting interpolation artifacts, for example, periodic artifacts. In one embodiment, these artifacts may be corrected in the frequency domain by convolution or median filter.

Embodiments of the present invention may include apparatuses for performing the operations herein. Such apparatuses may be specially constructed for the desired purposes (e.g., a "computer on a chip" or an ASIC), or may comprise general purpose computers selectively activated or reconfigured by a computer program stored in the computers. Such computer programs may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), electrically programmable read-only memories (EPROMs), electrically erasable and programmable read only memories (EEPROMs), magnetic or optical cards, or any other type of media suitable for storing electronic instructions.

The processes presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct a more specialized apparatus to perform the desired method. The desired structure for a variety of these systems appears from the description herein. In addition, embodiments of the present invention are not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the invention as described herein.

Unless specifically stated otherwise, as apparent from the discussions herein, it is appreciated that throughout the specification discussions utilizing terms such as "processing", "computing", "calculating", "determining", or the like, typically refer to the action and/or processes of a computer or computing system, or similar electronic computing device (e.g., a "computer on a chip" or ASIC), that manipulate and/or transform data represented as physical, such as electronic, quantities within the computing system's

registers and/or memories into other data similarly represented as physical quantities within the computing system's memories, registers or other such information storage, transmission or display devices.

5 While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made. Embodiments of the present invention may include other apparatuses for performing the operations herein. Such apparatuses may integrate the elements discussed, or may comprise alternative components to carry out the same purpose. It will be appreciated by persons skilled in the art that the appended claims
10 are intended to cover all such modifications and changes as fall within the true spirit of the invention.

CLAIMS

1. A method for transmitting image data to a receiving unit, the method comprising:

receiving a plurality of input data from an in vivo imaging
5 device corresponding to an image;
producing selected data from said plurality of input data; and
transmitting said selection data.

2. The method according to claim 1, wherein said producing
selected data includes at least producing selected data from said plurality of
10 input data according to a dilution pattern.

3. The method according to claim 2, wherein producing
selected data comprises modifying at least one input datum by reference to
at least one other input datum to produce selected data.

4. The method according to claim 3, wherein modifying said at
15 least one input datum comprises averaging said at least one input datum
with at least one other input datum.

5. The method according to claim 2, further comprising
interpolating reconstructed data based on said selected data.

6. The method according to claim 5, wherein interpolating said
20 reconstructed data comprises interpolating said reconstructed data based on
bicubic interpolation of selected data.

7. The method according to claim 5, further comprising
constructing a display image based on said selected data and said
reconstructed data.

25 8. The method according to claim 7, further comprising
enhancing said reconstructed data.

9. The method according to claim 8, further comprising
enhancing said selected data.

10. The method of claim 1, wherein said plurality of input data
30 includes at least a plurality of data corresponding to pixels, and wherein
producing said selected data from said plurality of input data comprises

producing said selected data by selecting a subset of said plurality of data corresponding to said pixels.

11. The method of claim 10, wherein said pixels are arranged in rows, and wherein selecting said subset of said plurality of data corresponding to said pixels comprises selecting data corresponding to every fourth pixel in each row respectively.

12. The method of claim 10, wherein said pixels are arranged in rows, and wherein selecting said subset of said plurality of data corresponding to said pixels comprises selecting no data from a first row, selecting data corresponding to every fourth pixel from a second and third row, respectively, and selecting data corresponding to every second pixel in a fourth row.

13. An in vivo imaging system comprising:

an imager configured to receive a plurality of input data corresponding to an image;

a transmitter to transmit a selection of said input data;

a receiver to receive said selection of input data; and

a processor to interpolate reconstructed data based on said selection of input data.

14. The in vivo imaging system of claim 11, wherein said imager is further configured to produce said selection of said input data.

15. The in vivo imaging system of claim 12, further comprising a display for viewing a display image corresponding to said selection of input data and said reconstructed data.

16. An in vivo device comprising:

an imager configured to receive a plurality of input data corresponding to an image; and

a controller configured to produce a selection of said input data.

17. The in vivo device of claim 14, wherein said controller is configured to produce said selection of said input data based on a dilution pattern.

18. The in vivo device of claim 15, wherein said controller is configured to produce said selection of input data by modifying an input datum by reference to at least one other input datum.

19. The device according to claim 15, wherein said controller is further configured to interpolate reconstructed data based on said selected data.

20. The device according to claim 17, wherein said controller is further configured to interpolate said reconstructed data based on bicubic interpolation of selected data.

21. The device according to claim 17, wherein said controller is further configured to enhance said reconstructed data.

22. The device of claim 14, wherein said plurality of input data includes at least a plurality of data corresponding to pixels, and wherein said controller is configured to produce said selected data by selecting a subset of said plurality of data corresponding to said pixels.

23. An in vivo device comprising:

input means for receiving a plurality of input data corresponding to an image; and

selection means for producing a selection of said input data.

24. The device according to claim 21, further comprising averaging means for modifying at least one input datum by reference to at least one other input datum to produce selected data.

25. The device according to claim 21, further comprising transmission means for transmitting said selection of said input data.

26. A method for transmitting image data to a receiving unit, the method comprising:

receiving a plurality of input pixel data corresponding to an in vivo image;

selecting a portion of said input pixel data from said plurality of input pixel data according to a dilution pattern; and

transmitting said portion of said input pixel data.

27. An in vivo imaging device comprising:

an imager capable of receiving a plurality of input data corresponding to an image and producing a selection of said input data;

a transmitter capable of transmitting said selection of said input data;

a receiver capable of receiving said selection of input data; and

a processor capable of interpolating reconstructed data based on said selection of input data.

28. The method according to any of claims 1-12, 26 substantially as described hereinabove.

29. The method according to any of claims 1-12, 26 substantially illustrated in any of the drawings.

30. The in vivo imaging system according to any of claims 13-15 substantially as described hereinabove.

31. The in vivo imaging system according to any of claims 13-15 substantially illustrated in any of the drawings.

32. The device according to any of claims 16-25, 27 substantially as described hereinabove.

33. The device according to any of claims 16-25, 27 substantially illustrated in any of the drawings.

For the Applicant



Eitan, Pearl, Latzer & Cohen-Zedek
Lawyers, Patent Attorneys & Notaries

P-4333-IL1

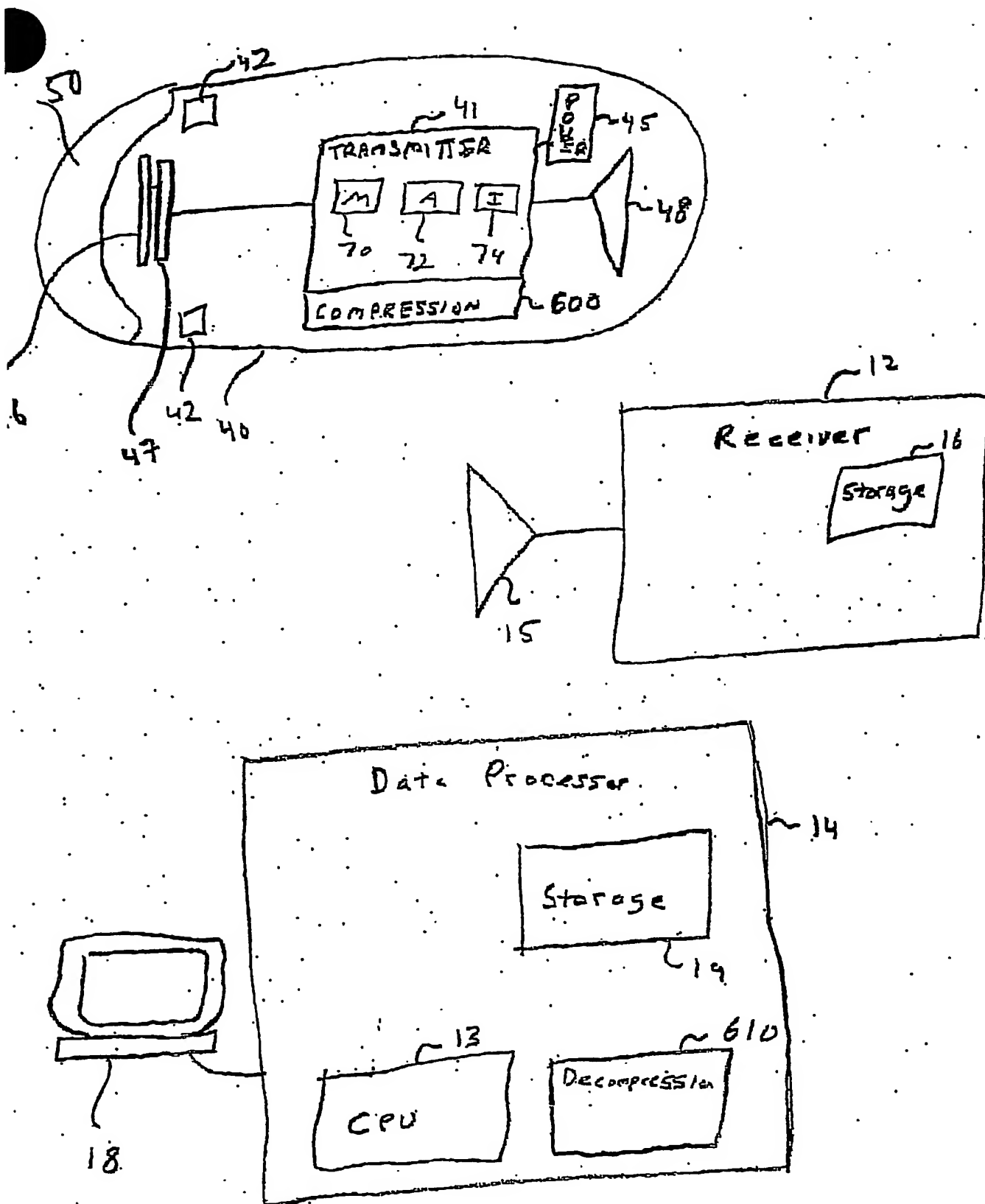


Fig. 1.

[P-4333-US]

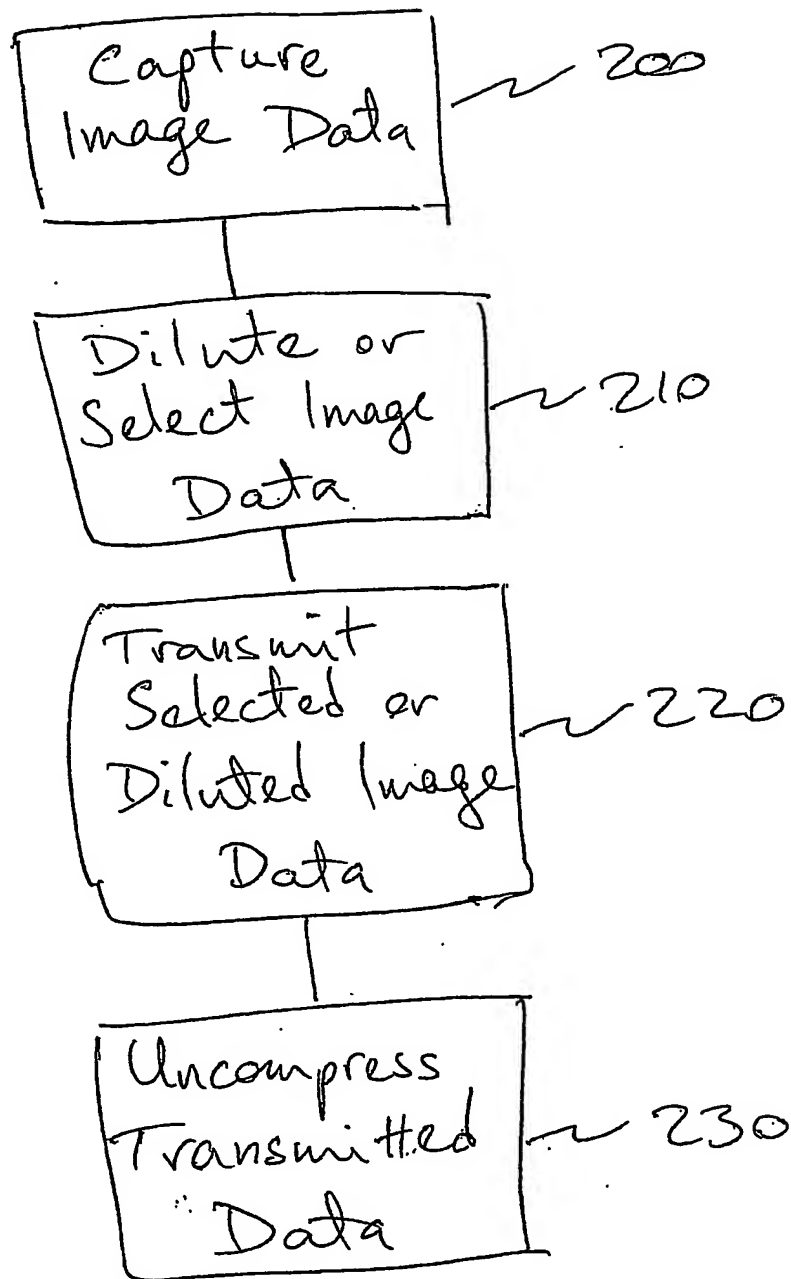


Fig. 2



Fig. 3

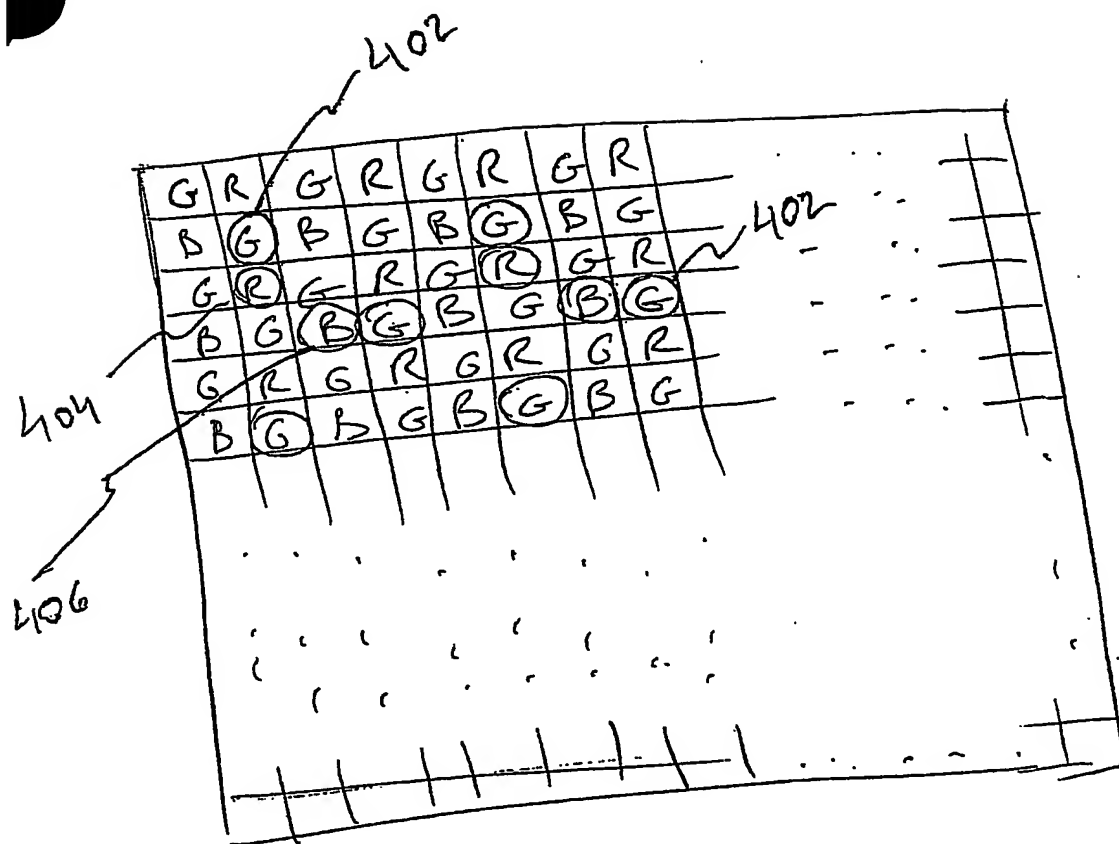


Fig. 4

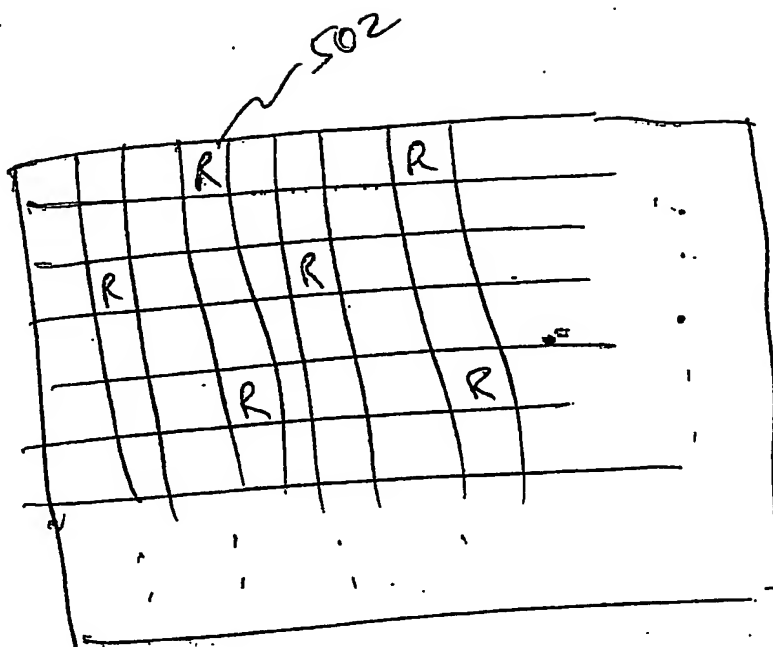


Fig. 5

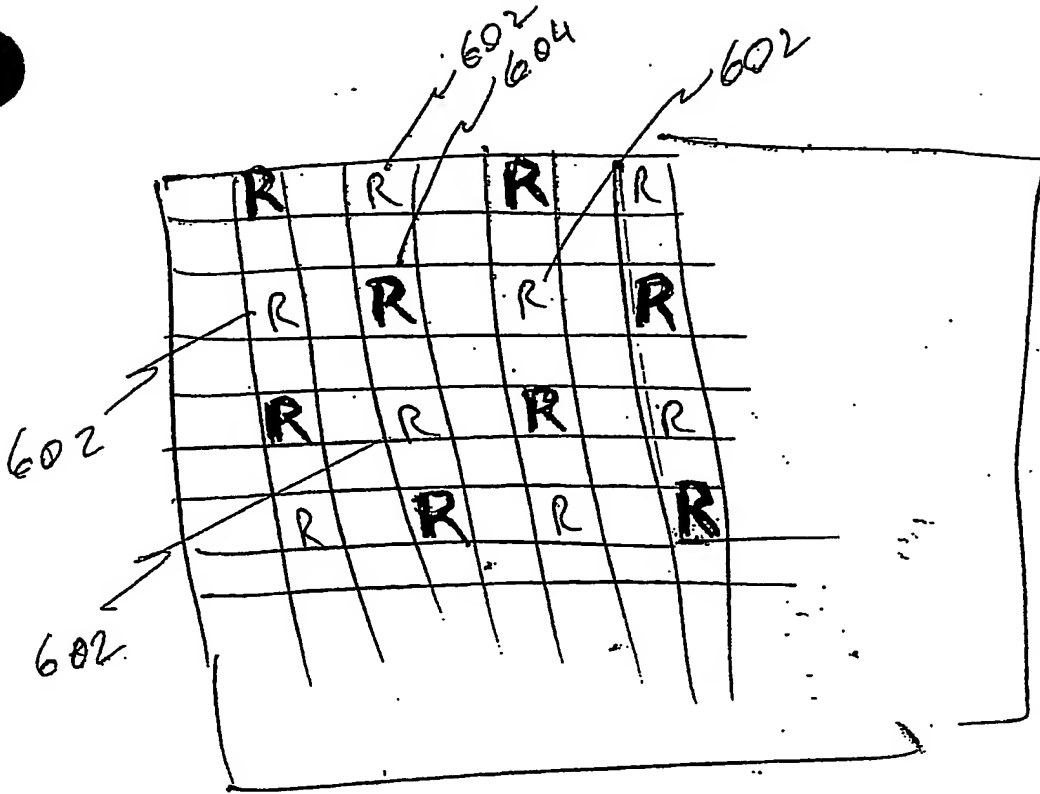


Fig. 6

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